# Environmental drivers of macroinvertebrate stability and persistence within the Interior Columbia River Basin, USA

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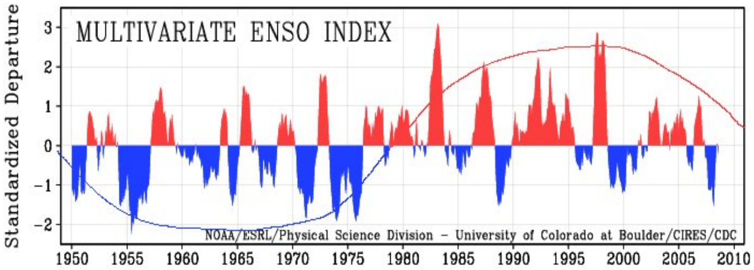
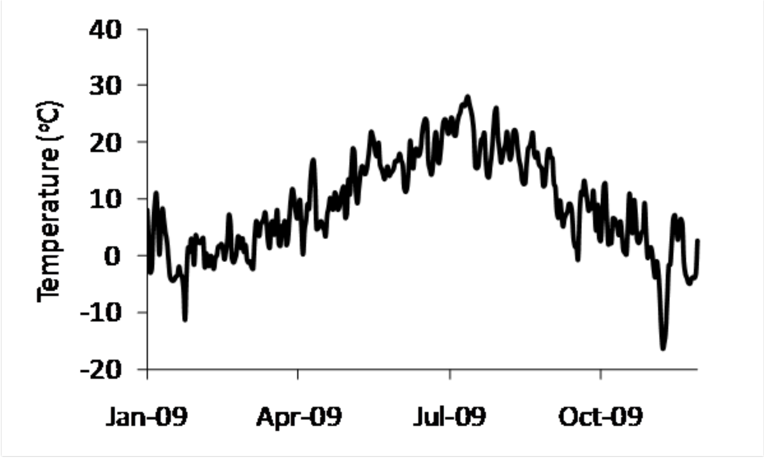
# Introduction

- Lotic macroinvertebrates inhabit temporally variable environments




- Primary environmental drivers:
  - Climatic variability
    - Decadal
    - Annual
    - Seasonal

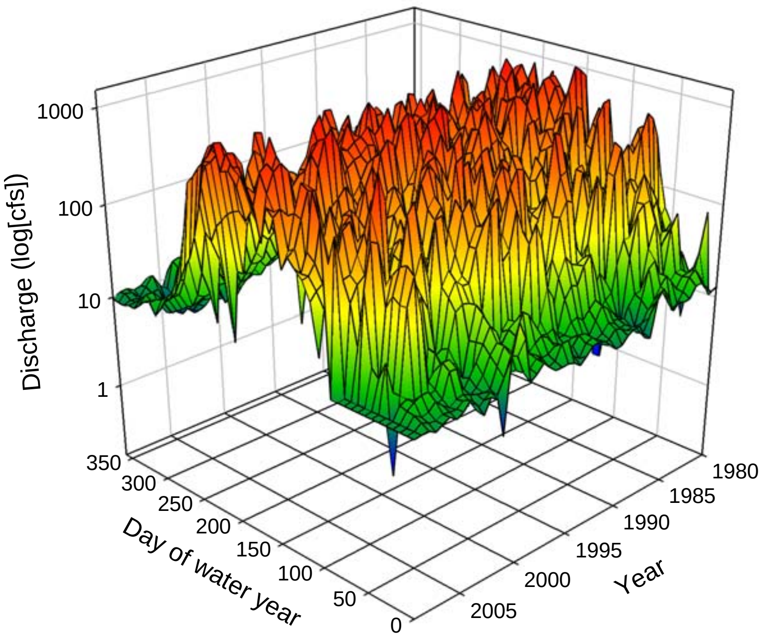


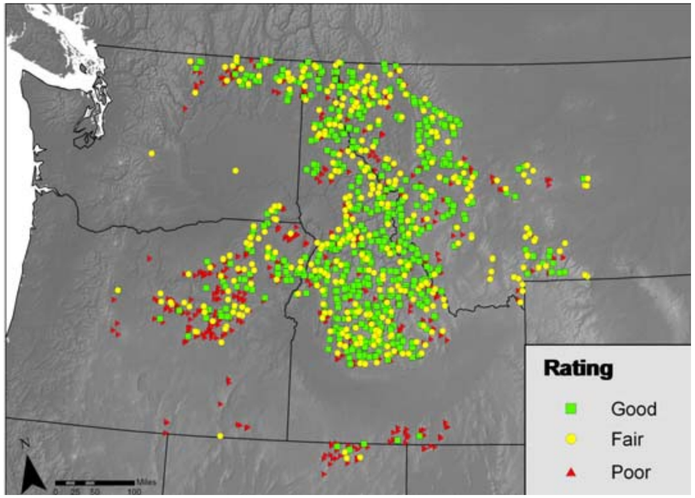

  - Disturbance
    - Press or pulse
    - Natural or anthropogenic

# Introduction

- Abiotic/biotic responses
  - Discharge
  - Temperature
  - Substrate
  - Food resources
  - Habitat quantity

- Knowledge of how temporal environmental variability structures assemblage dynamics is poor

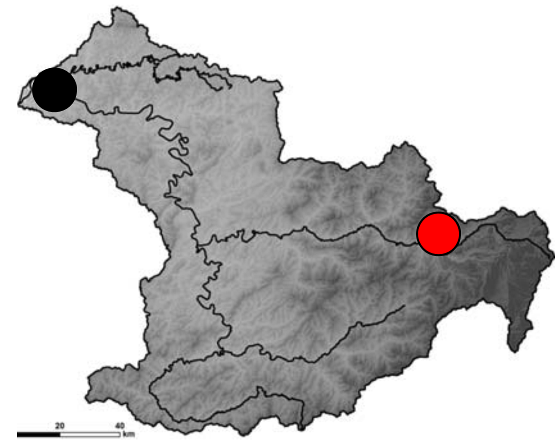



Regional–scale assessment

# Introduction

- Paucity of interannual and decadal studies
  - Recent decadal-scale studies, but limited in geographic scope
- Likely site x year interactions = differential change among sites through time:
  - Climatic patterns
  - Watershed attributes
  - Biological composition



Reference

Disturbed

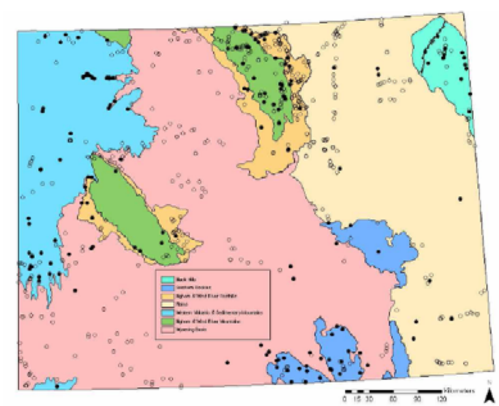
# Introduction: Status and Trend Monitoring

Pervasiveness of trend monitoring:

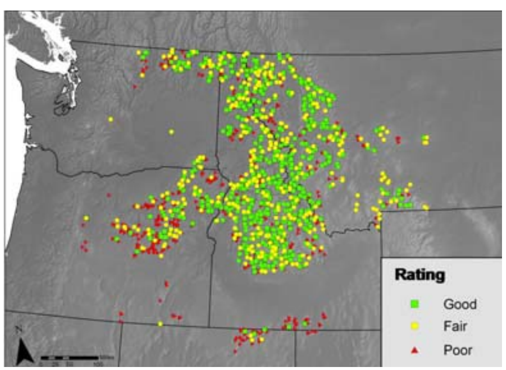
- 75% of the 2022 samples submitted to NAMC (aka the BugLab) for processing in 2009 were attempting to detect temporal trends

Restoration effectiveness monitoring

State monitoring programs

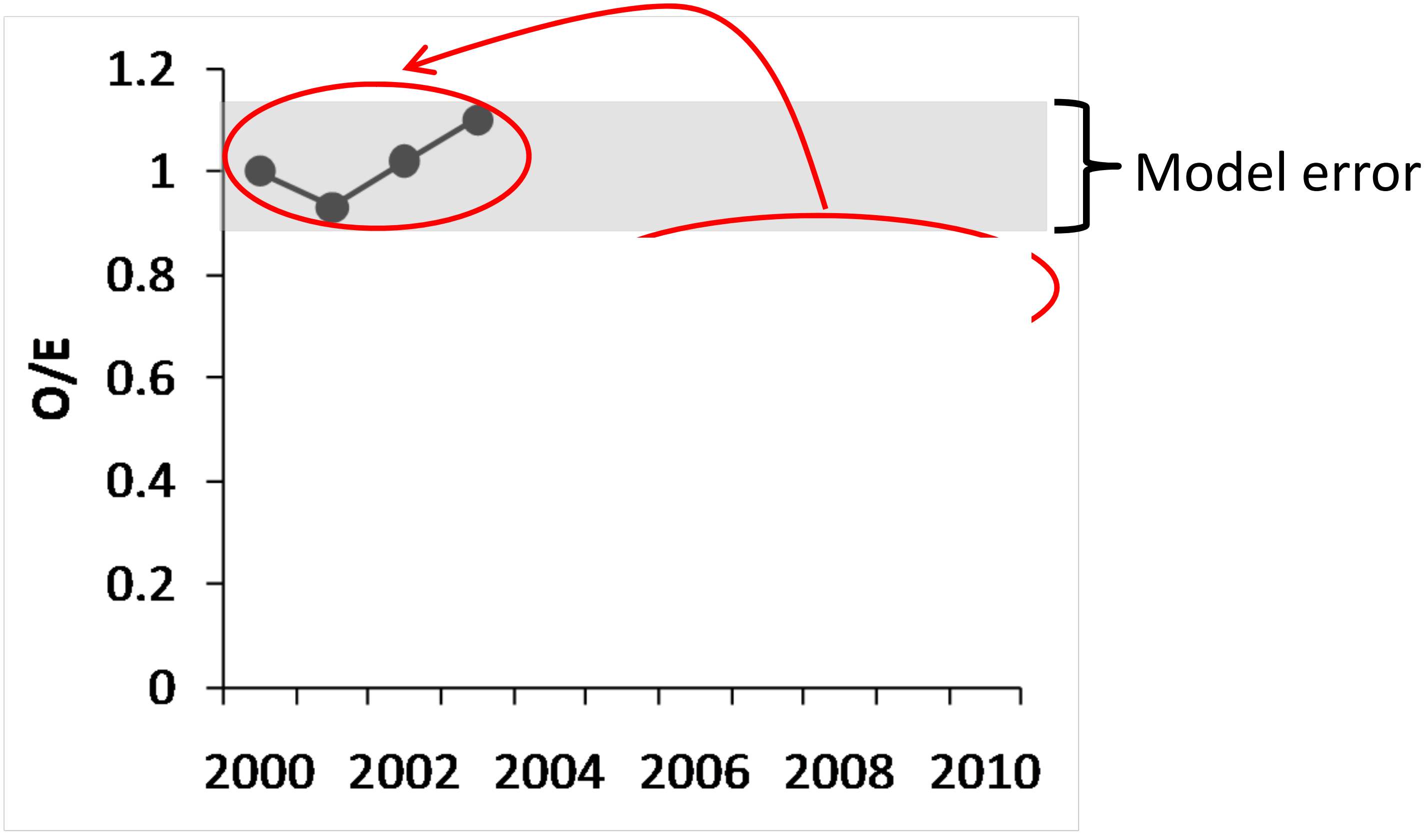


Regional assessments



# Introduction: Status and Trend Monitoring

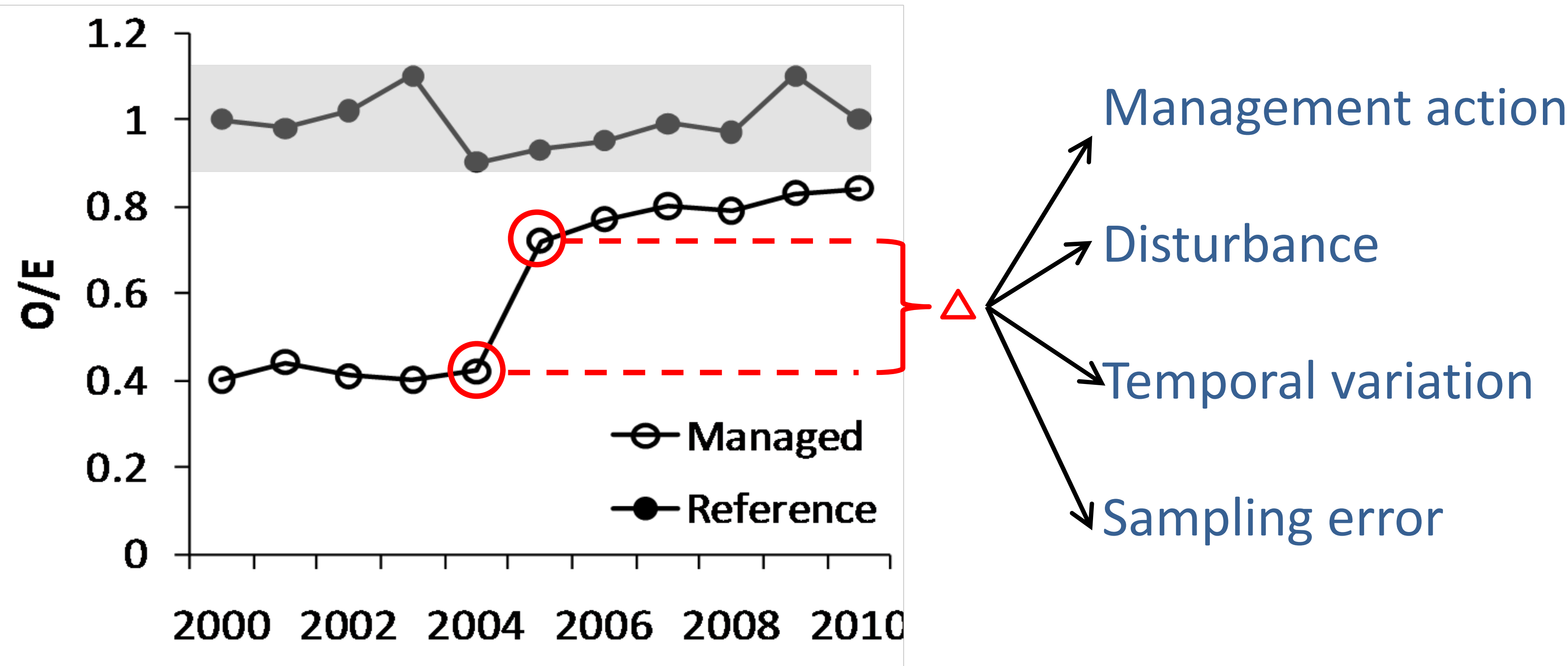
*Assumptions:*
- Reference conditions are static



# Introduction: Status and Trend Monitoring

*Assumptions:*

- Reference conditions are static
- Accurate variance partitioning:



# Research questions

1. Does macroinvertebrate persistence (assemblage composition) and stability (relative abundance) differ among sites and years?

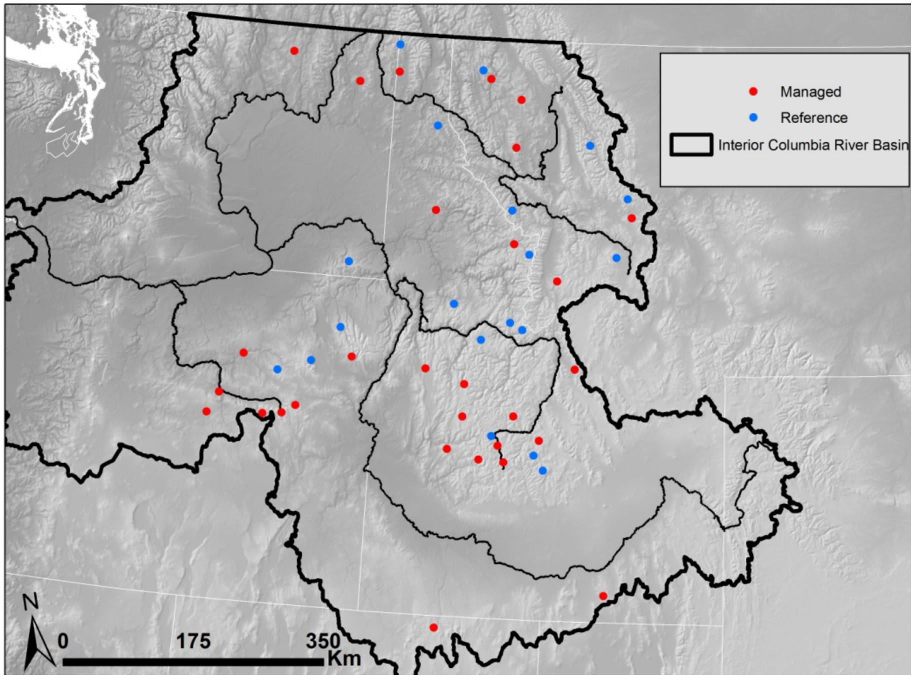
2. Why do some sites change more than others?

3. What components of interannual environmental variability explain macroinvertebrate temporal dynamics?

# Methods: Study design

<u>USFS PIBO EM Dataset</u>

- Interior Columbia River Basin
- Are current mngt. practices maintaining or improving stream habitat?
- Random sampling of ~300 6th field HUCs/yr
- 48 randomly selected 'Sentinel' sites/yr
  - 19 Reference
  - 29 Managed




Rotating panel design

| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|
| Sentinel Sites | X | X | X | X | X | X | X | X | X |
| Integrator Sites-2001-2006 | X | | | | | X | | | |
| Integrator Sites-2002-2007 | | X | | | | | X | | |
| Integrator Sites 2003-2008 | | | X | | | | | X | |
| Integrator Sites 2004-2009 | | | | X | | | | | X |

# Methods: Relevant field measurements

48 Sites sampled from 2001-2008: 311 total sample events

Aquatic macroinvertebrates

- 2 Surber samples from 4 fast water habitats

Environmental parameters (20 x bankfull)

- Conductivity
- Bankfull width
- Gradient
- Pool frequency
- Substrate
- Bank stability
- Frequency of LWD
- Temperature

# Methods: Analytical approach

Characterizing macroinvertebrate temporal dynamics:

- **Persistence**: continued presence of species through time
  - Bray-Curtis dissimilarity of presence-absence
- **Stability**: Degree of constancy in numbers
  - Bray-Curtis dissimilarity of relative abundance
- **Biological condition**: RIVPACS model developed from multi-year sampling of >300 reference sites



# Methods: Analytical approach

## Predictors of macroinvertebrate persistence and stability:

**Reach**:
- *Conductivity*
- *Bankfull width*
- *Gradient*
- *Pool frequency*
- *Substrate*
- *Bank stability*
- *LWD freq.*
- *Temperature*
- *O/E*

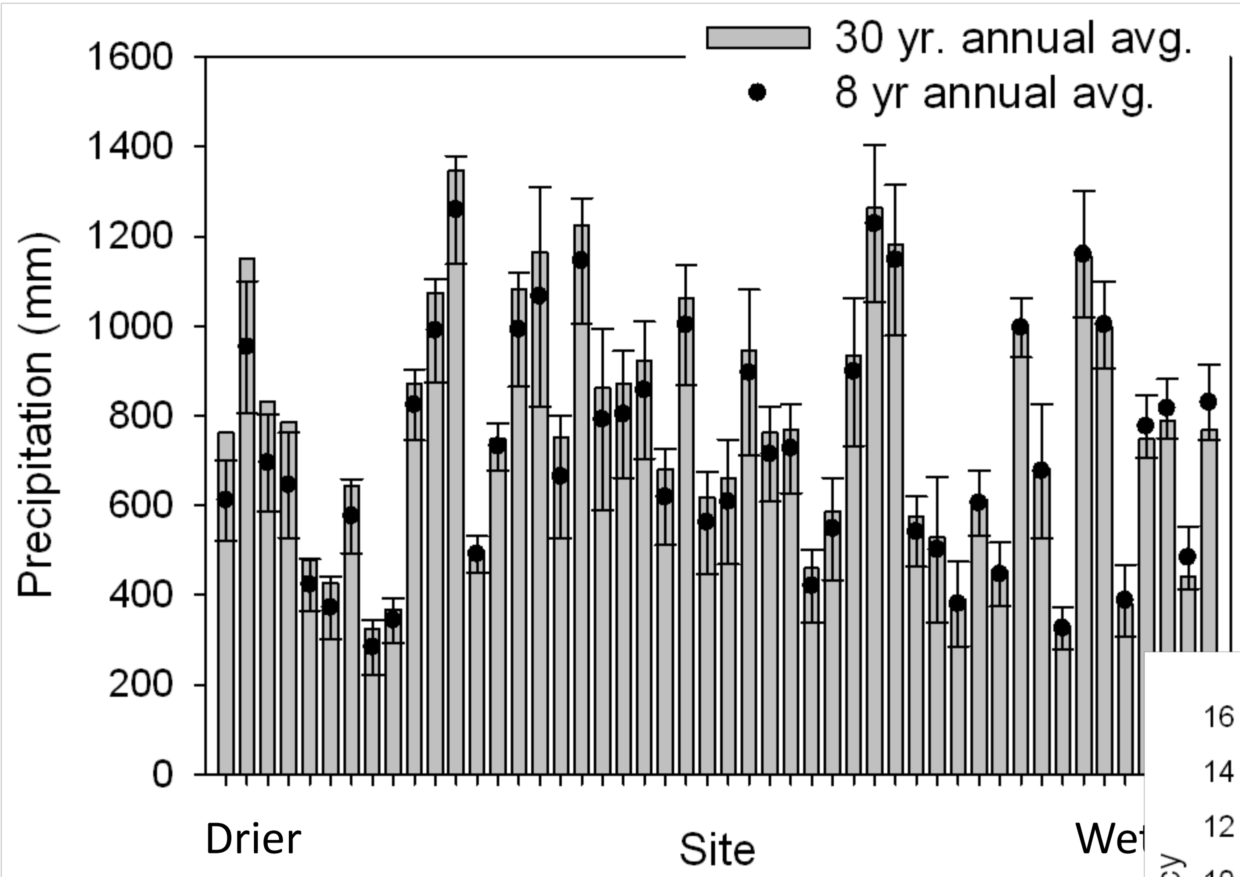
**Watershed**:
- Area
- Elevation
- Stream density
- $CaCO_3$
- Erosiveness
- % igneous
- % metamorphic
- % sedimentary

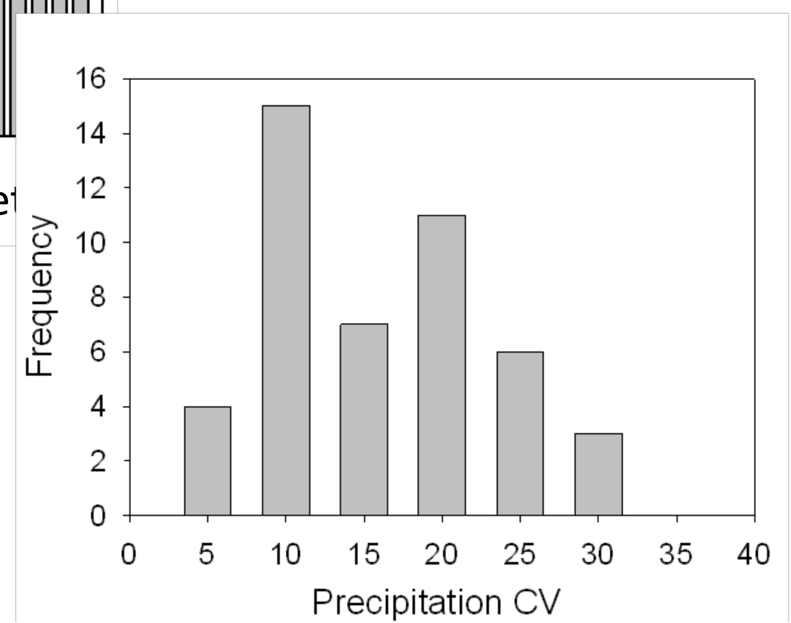
**Disturbance**:
- Road density
- % forested
- % burned
- % grazed

**Climatic**:
- *Temperature*
- *# frost days*
- *Precipitation*
  - *30 yr avg.*
  - *1 month*
  - *3 months*
  - *12 months*

*Italicized variables were measured/computed annually*

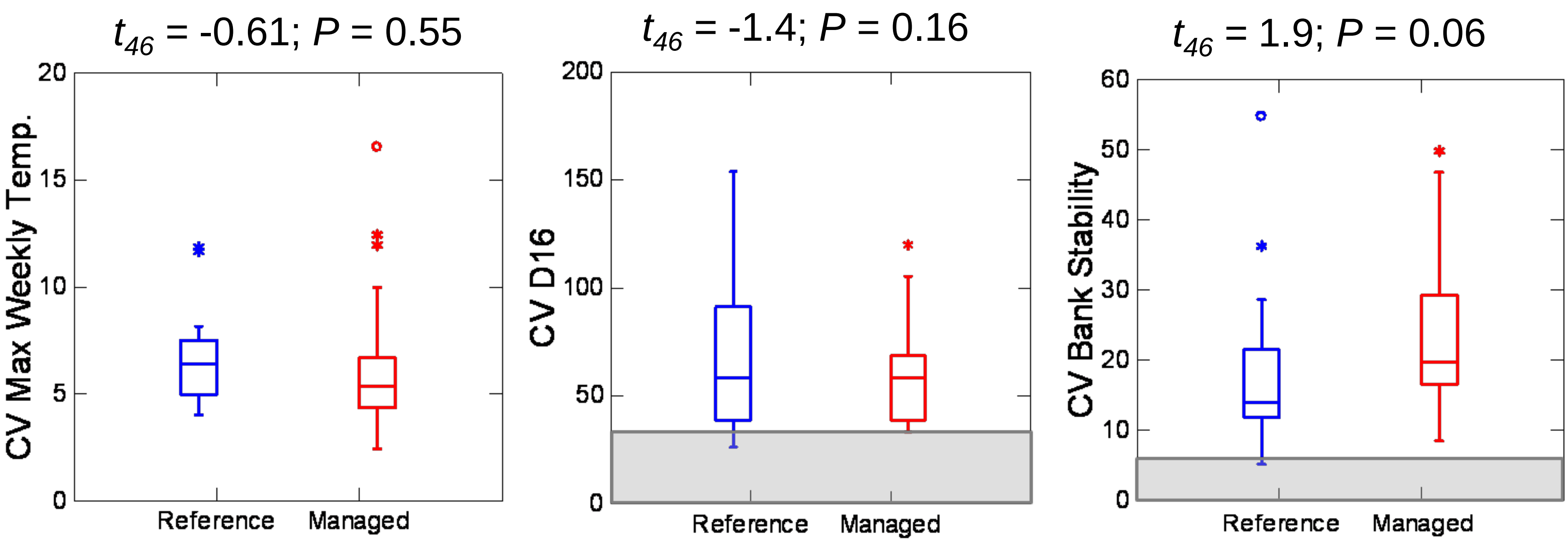
# Results: Climatic variability



# Results: Reach-scale variability

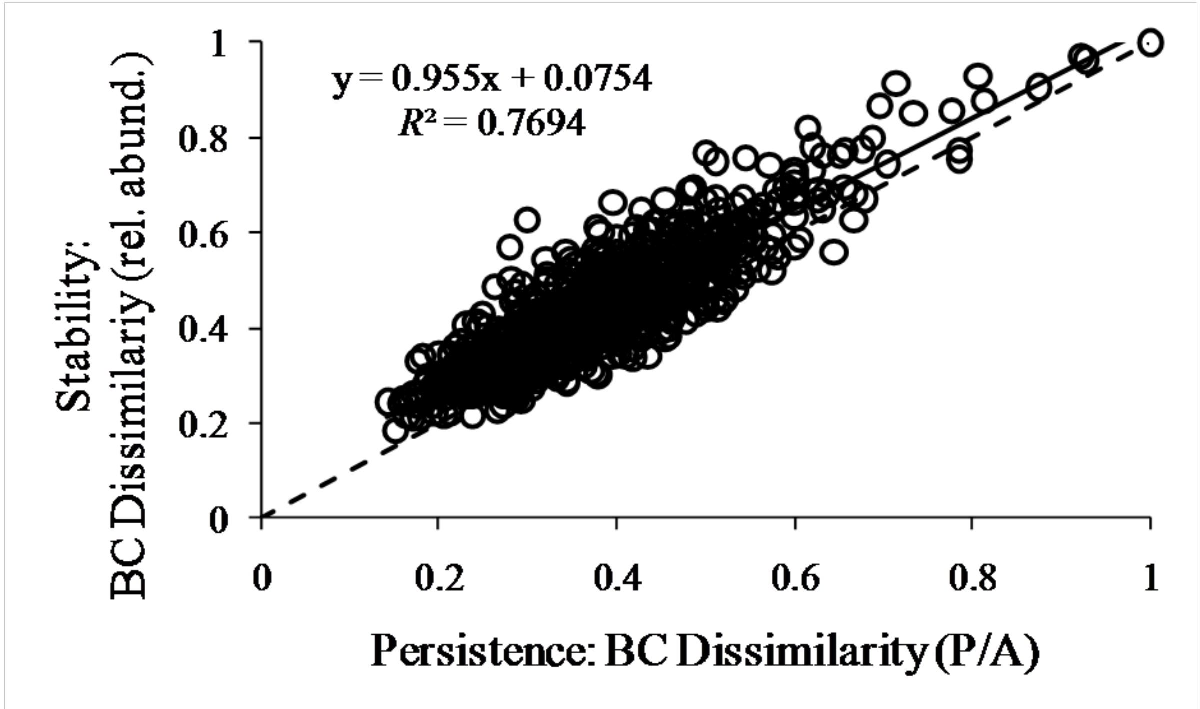
- When quantified, temporal variability exceeded sampling error
- CV > 25%: Conductivity, D16, D50, Bank stability, % LWD
- Temporal variability consistent between ref. and mngt.



# Results: Persistence versus stability

- Strong relationship between persistence and stability

- Stability consistently higher:
  - Contribution of core taxa more consistent than relative abundance of same taxa
  - Persistence more conservative response variable

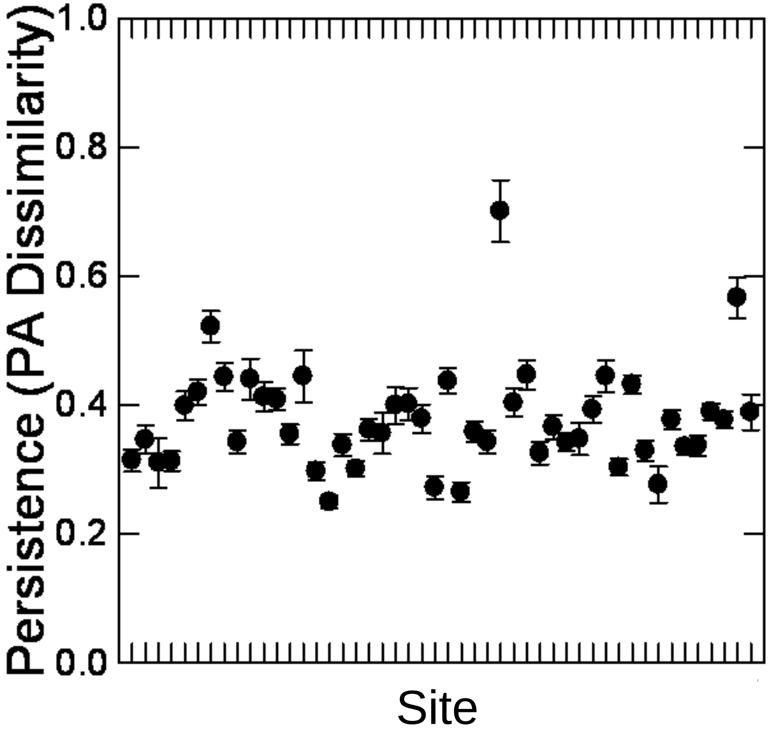


# Does macroinvertebrate persistence (assemblage composition) differ among sites and years?

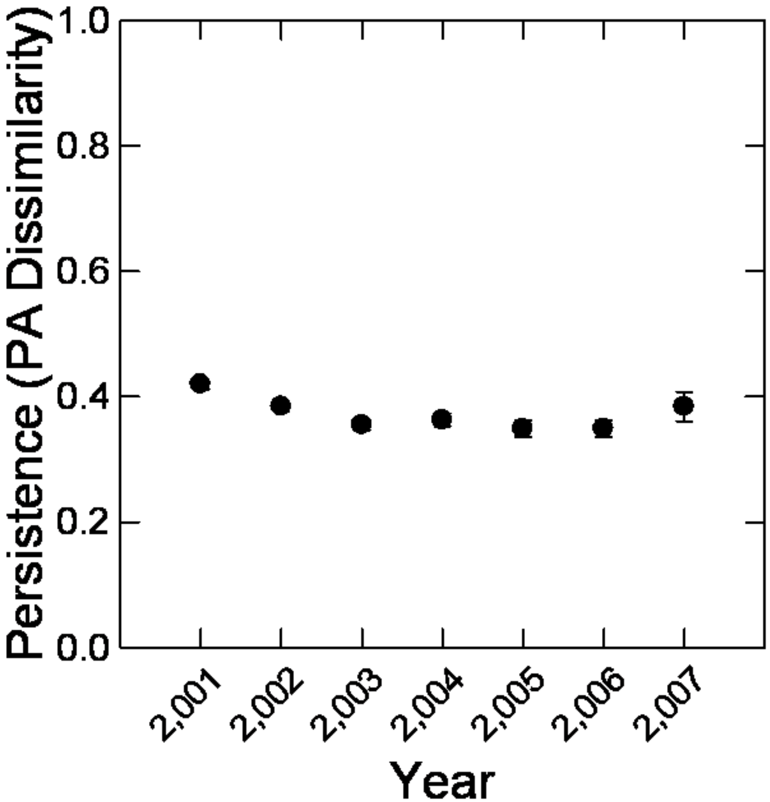
# Results: Persistence compared among sites & years

## Significant site and year effect for persistence

Average Persistence among sites
$F_{47} = 14.3$; $p = < 0.001$

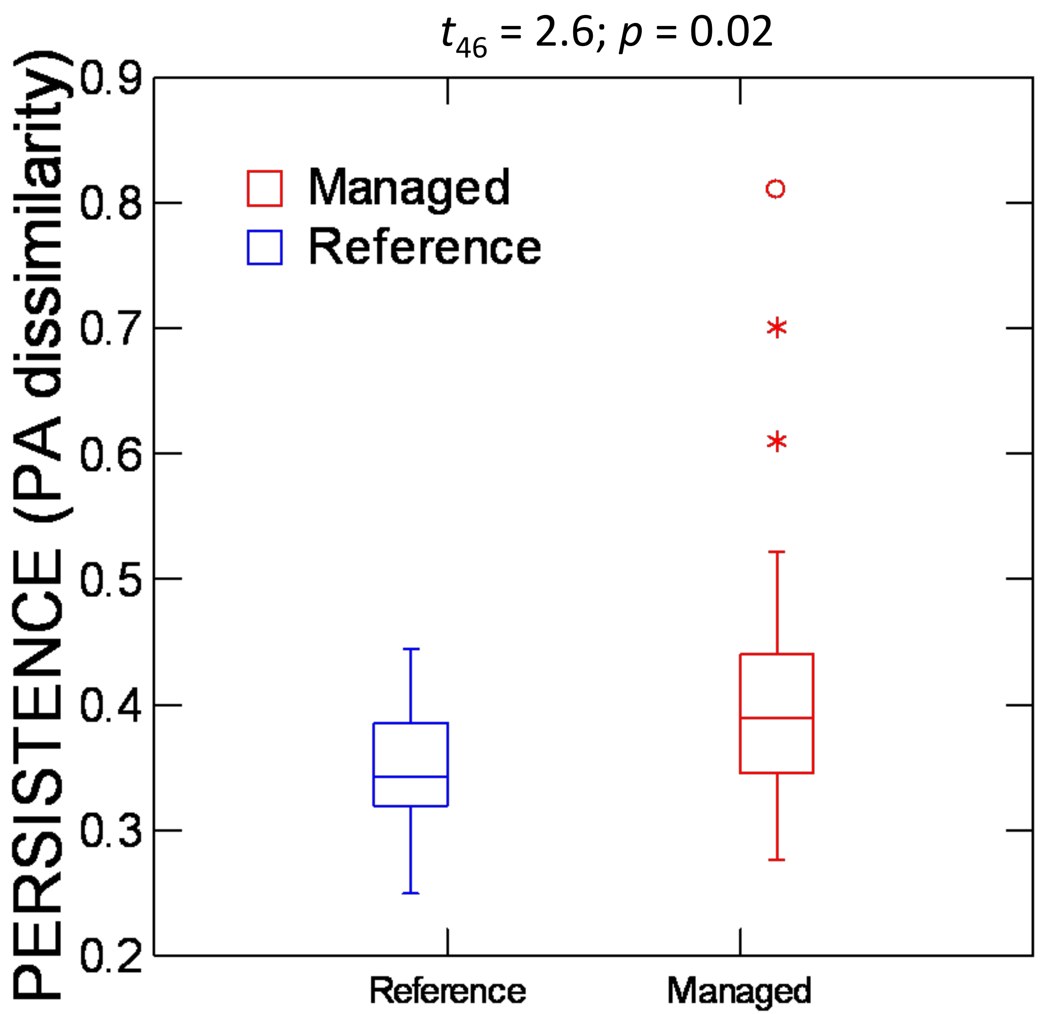



Average Persistence among years
$F_6 = 11.56$; $p = < 0.001$



# Results: Persistence compared among sites & years

## Moderate differences between reference and managed sites



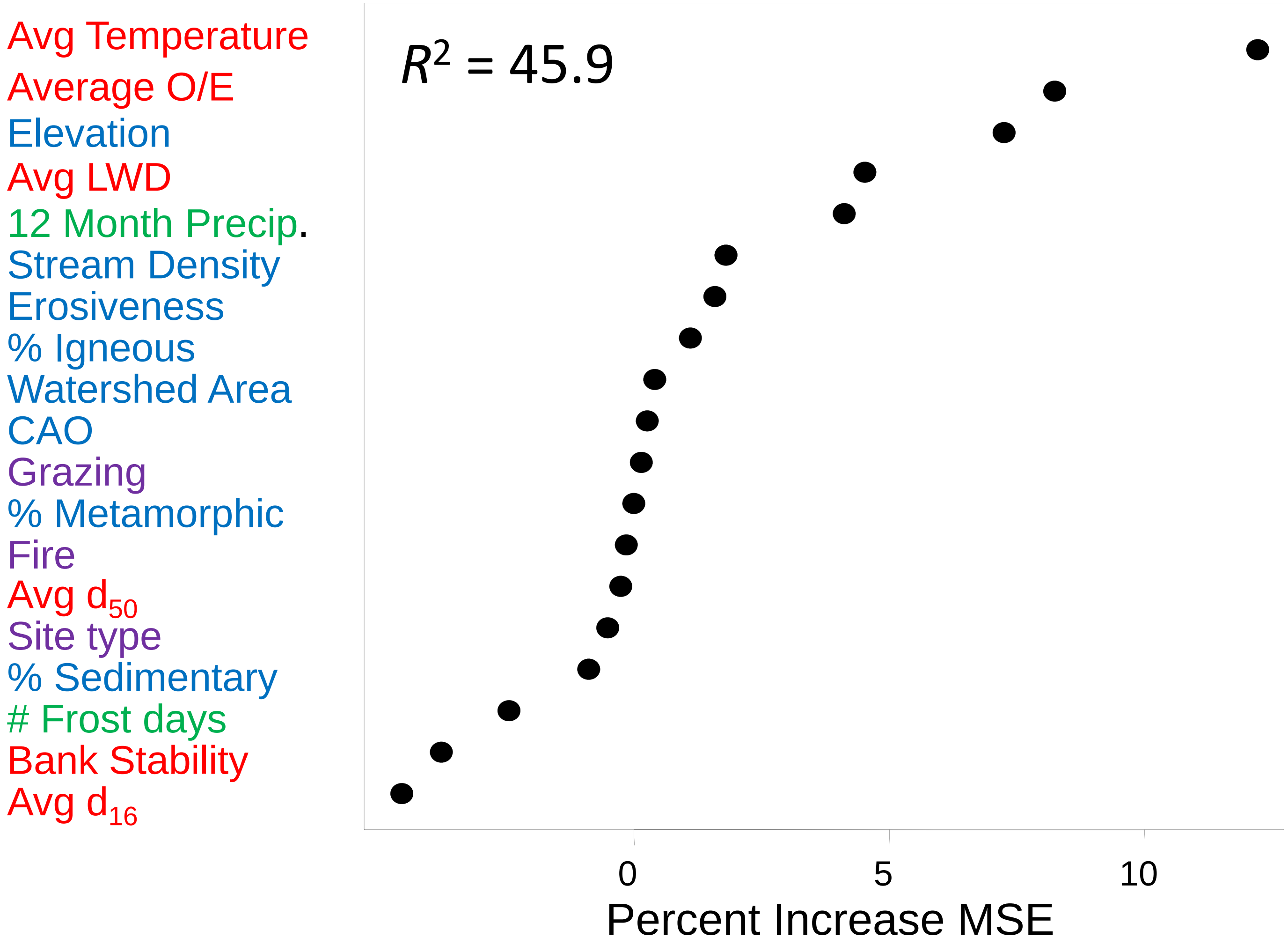
Why do some sites change more than others?

# Results: Why do some site change more than others?

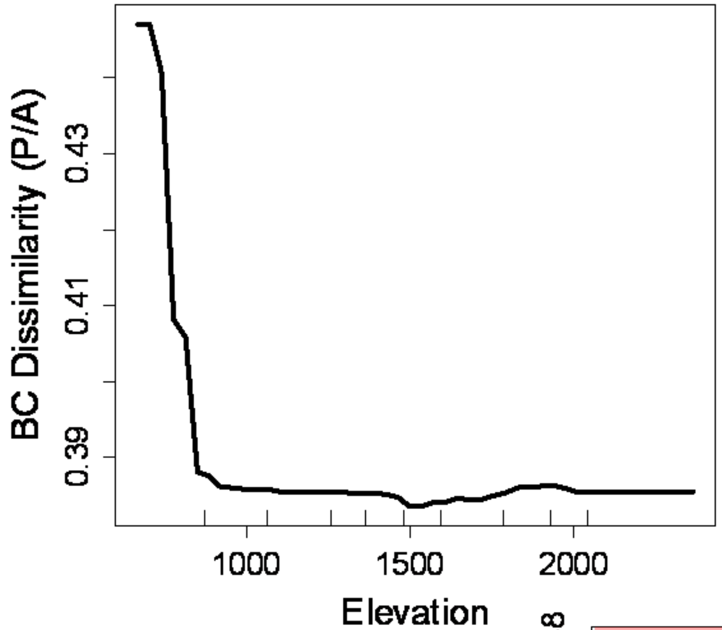
*Modeling approach*: Random forest

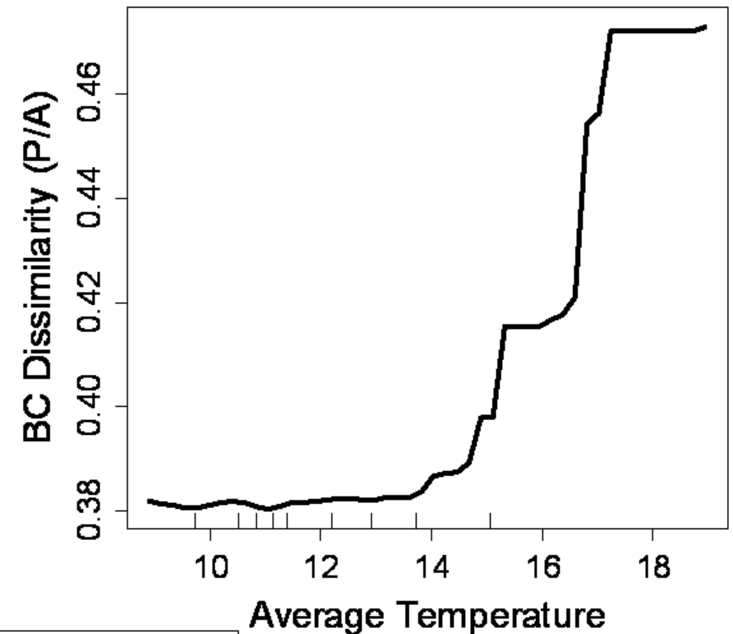
*Response*: Avg. macroinvertebrate persistence

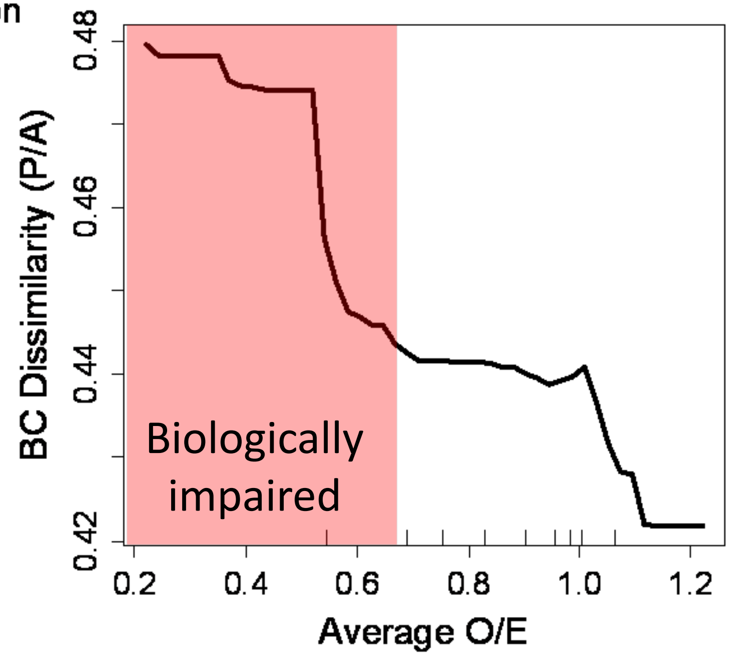
*Explanatory variables*: reach avg., watershed, climatic, disturbance



# Results: Why do some site change more than others?

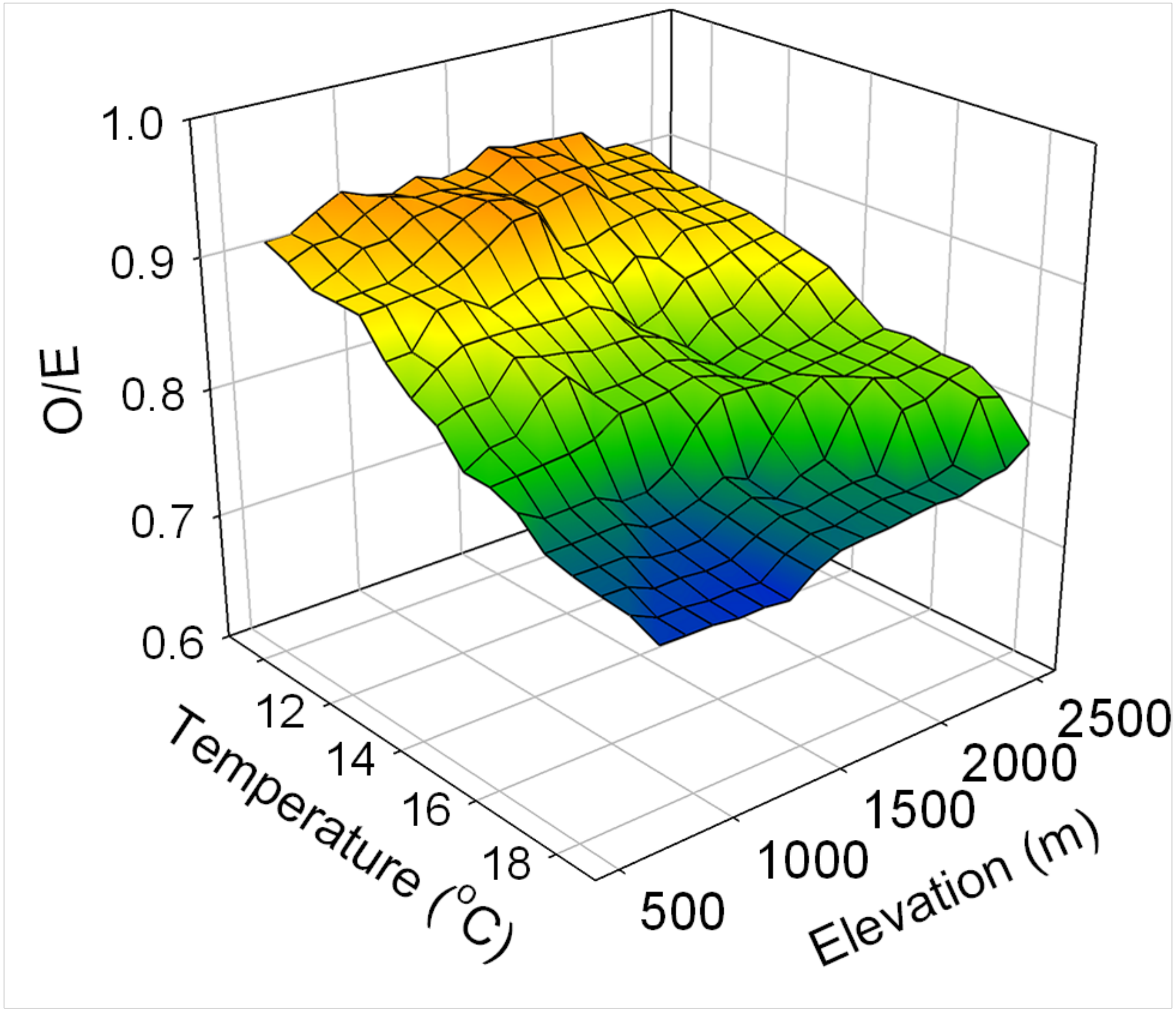


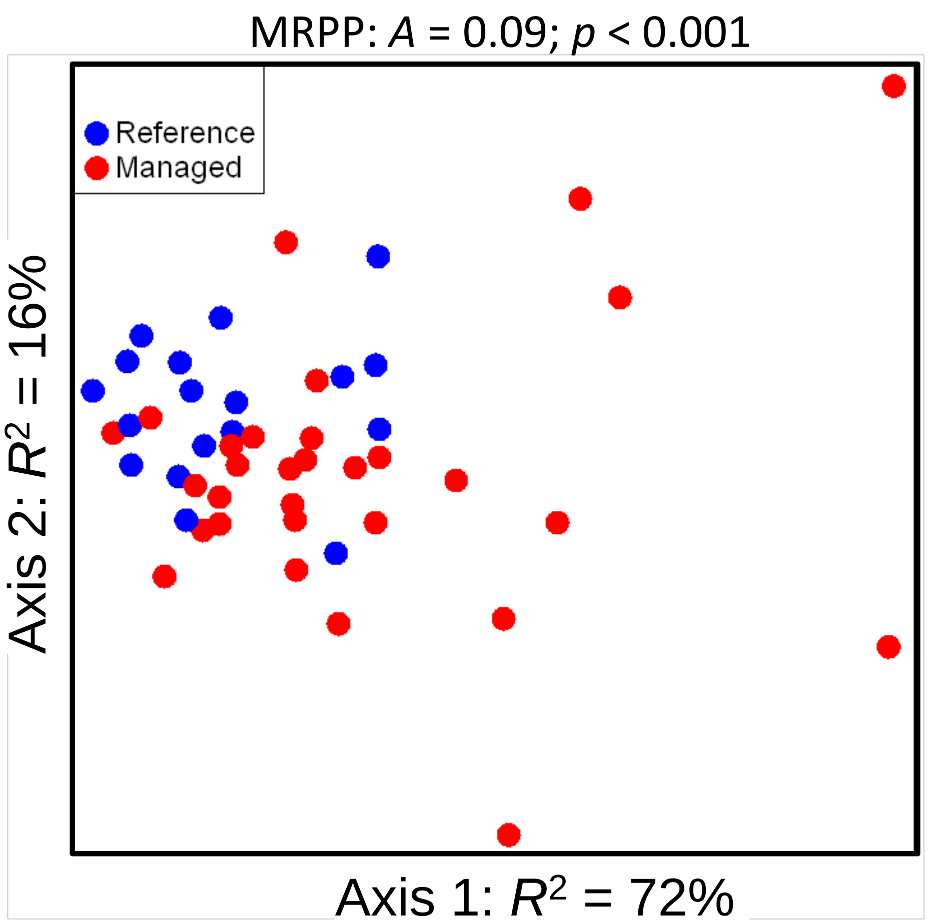
# Results: Why do some site change more than others?

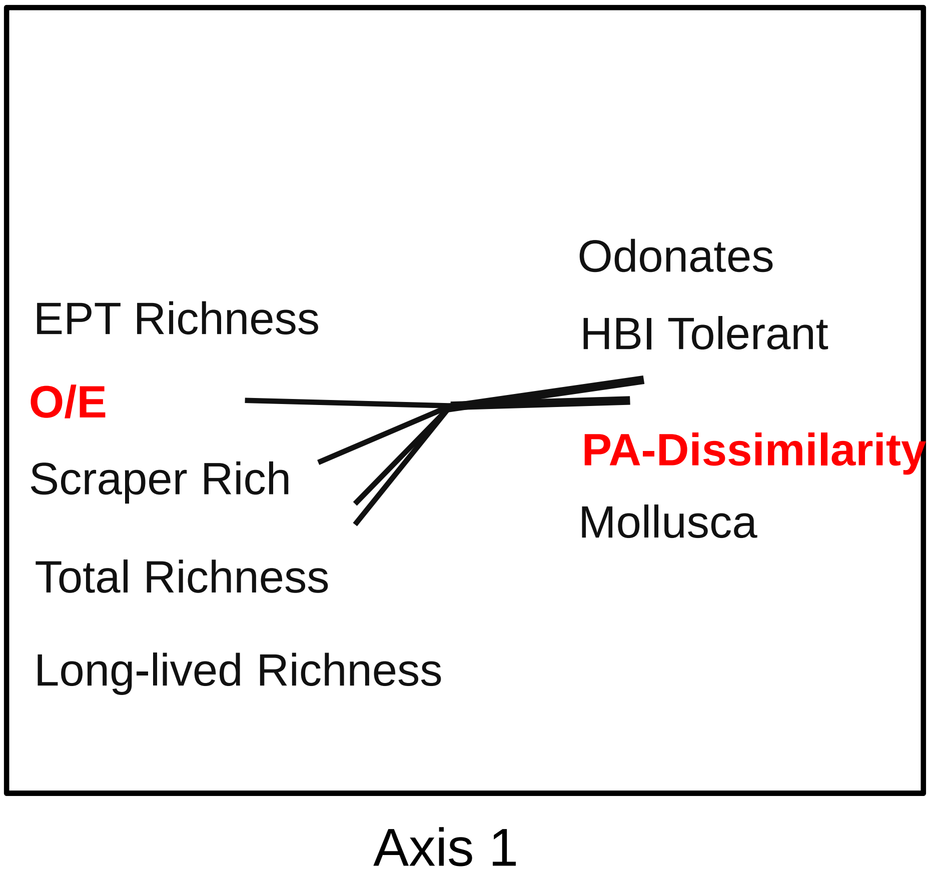
Biological condition as a function of temperature and elevation



# Results: Why do some site change more than others?

## NMDS ordination of macroinvertebrate presence/absence

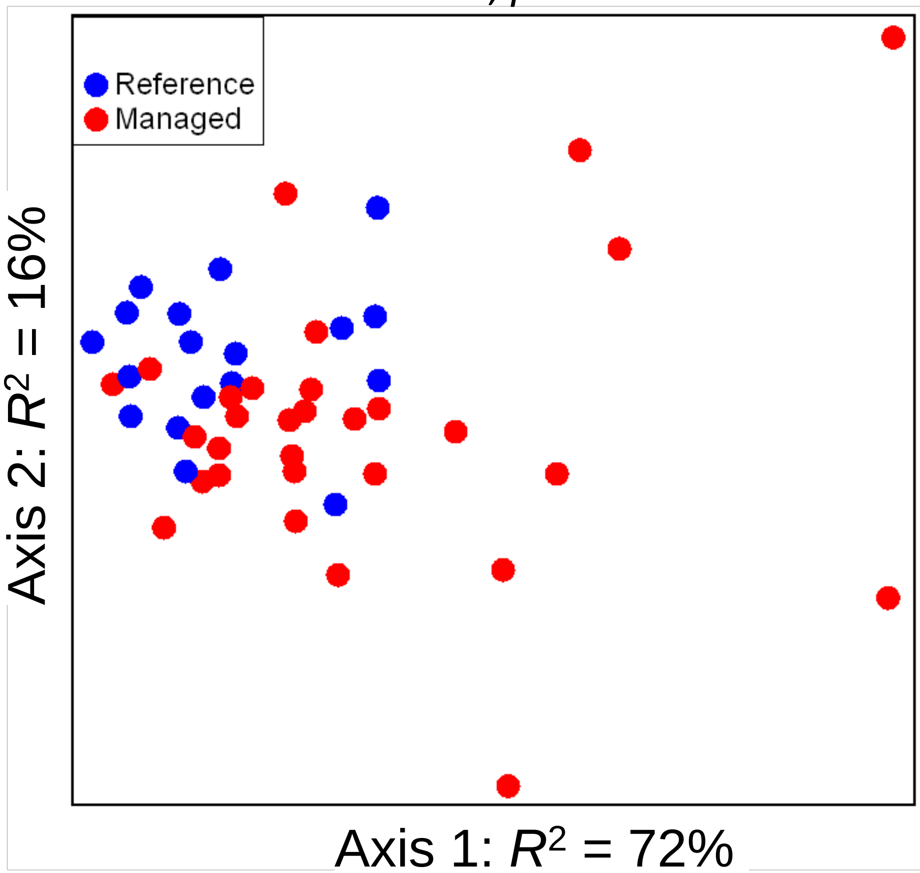


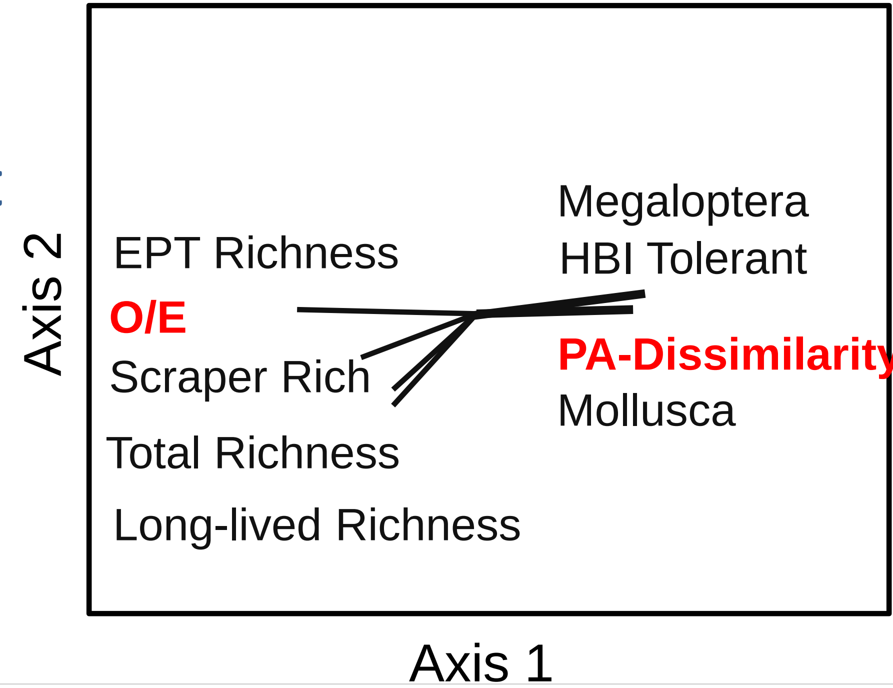



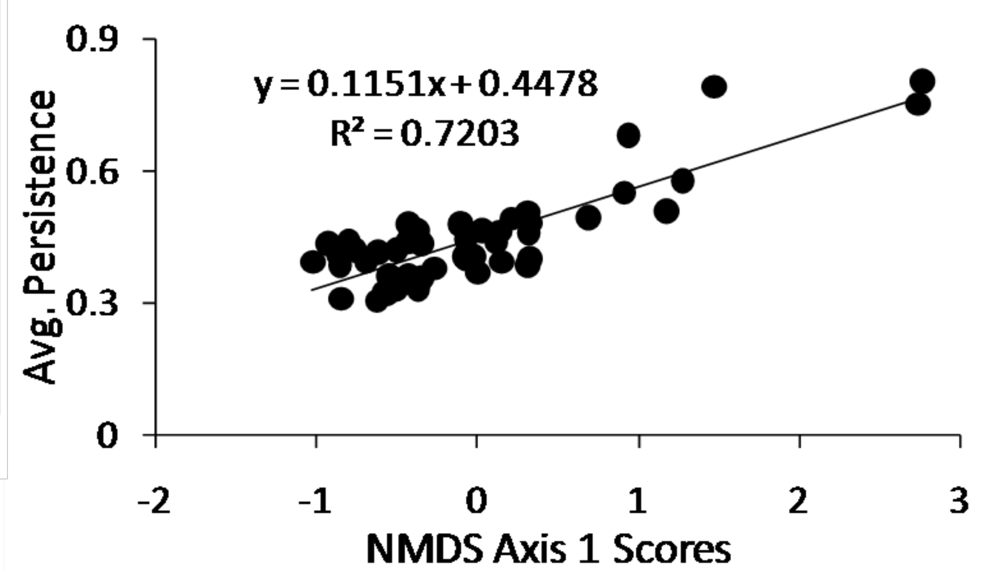
# Results: Why do some site change more than others?

## Disturbance adapted assemblages are less persistent

MRPP: $A = 0.09$; $p < 0.001$



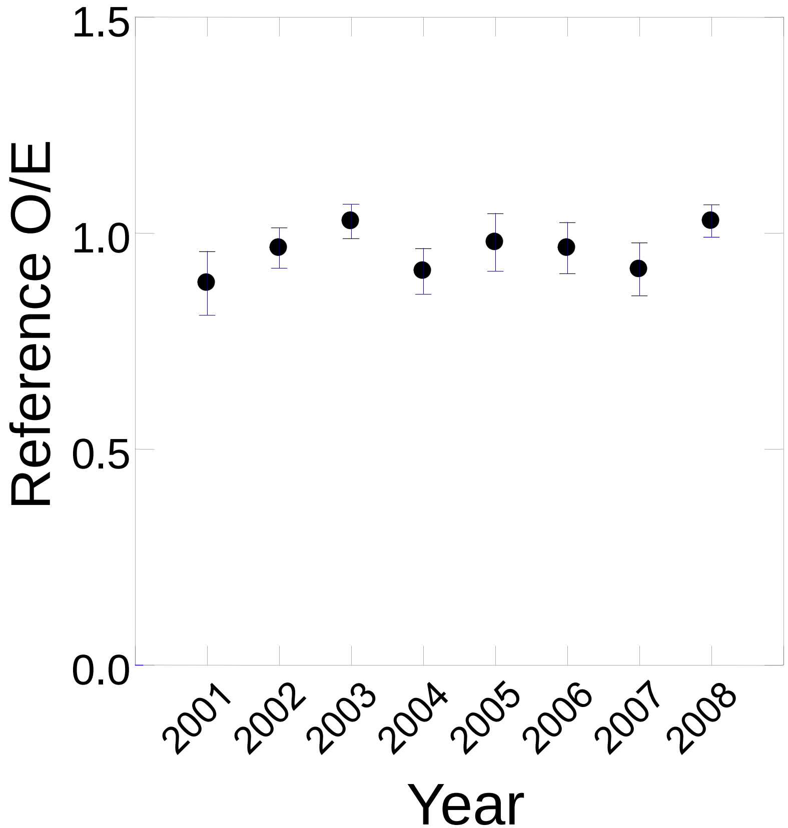



Is the observed year effect ecologically significant?

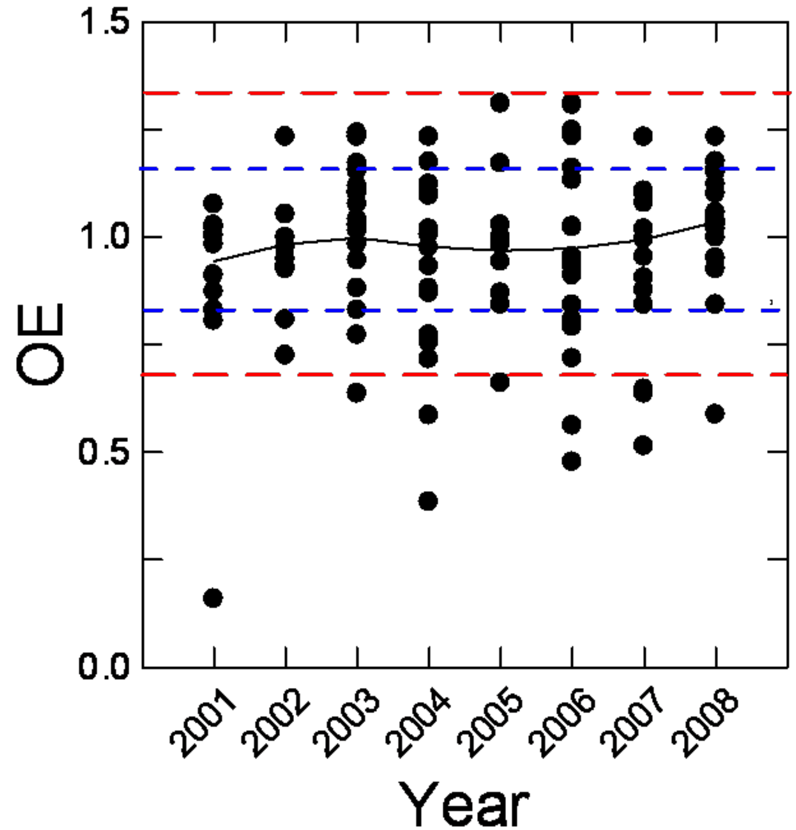
# Results: Is the year effect ecologically significant?

## Reference site O/E scores among years

$F_7 = 1.54$; $p = 0.195$



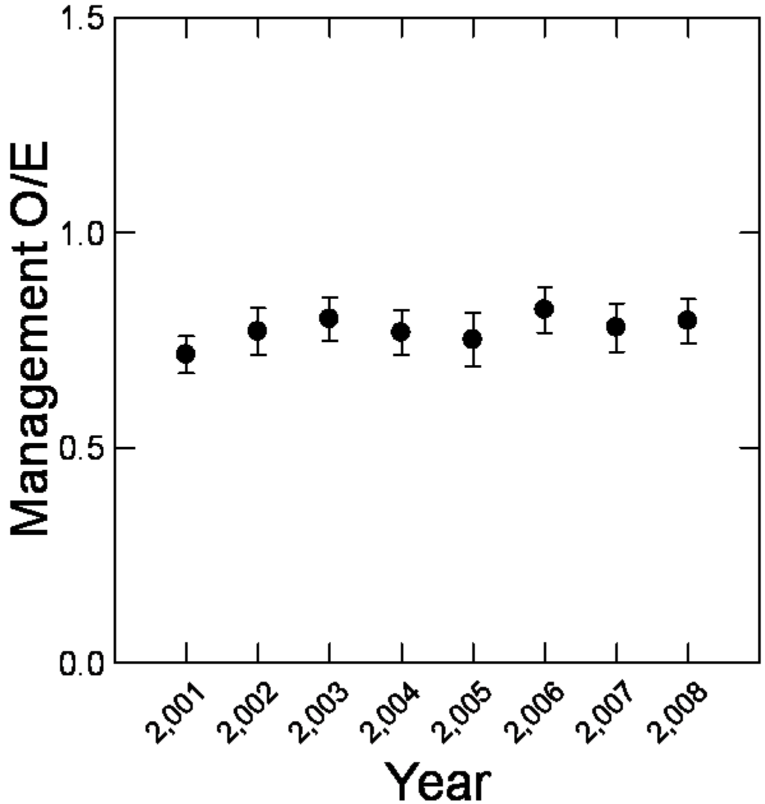

22% of obs. > model error
9% of sites / 4% of obs. > 2x model error



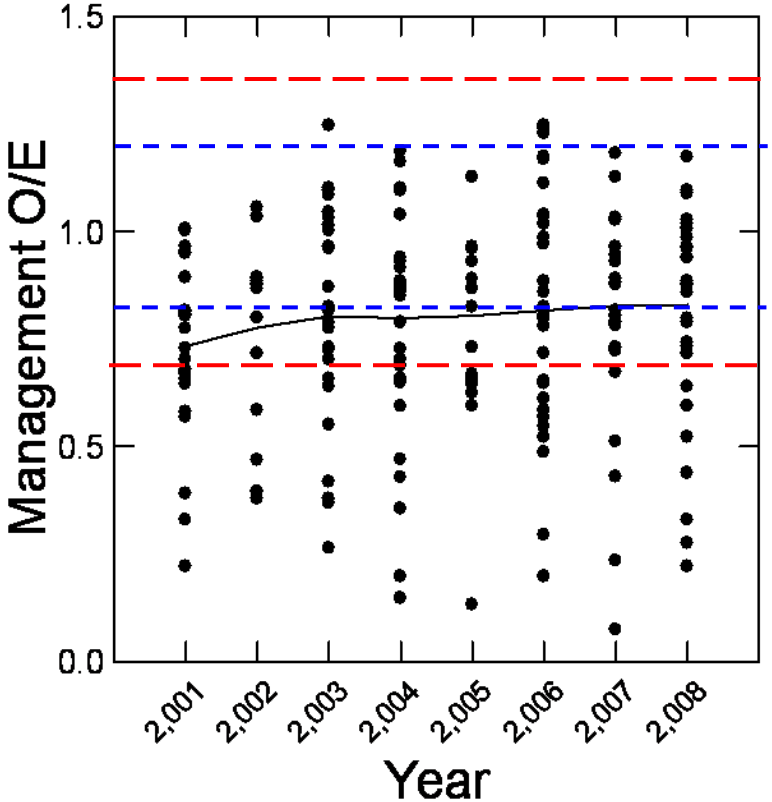
# Results: Is the year effect ecologically significant?

## Managed site O/E scores among years

$F_7 = 0.41$; $p = 0.801$

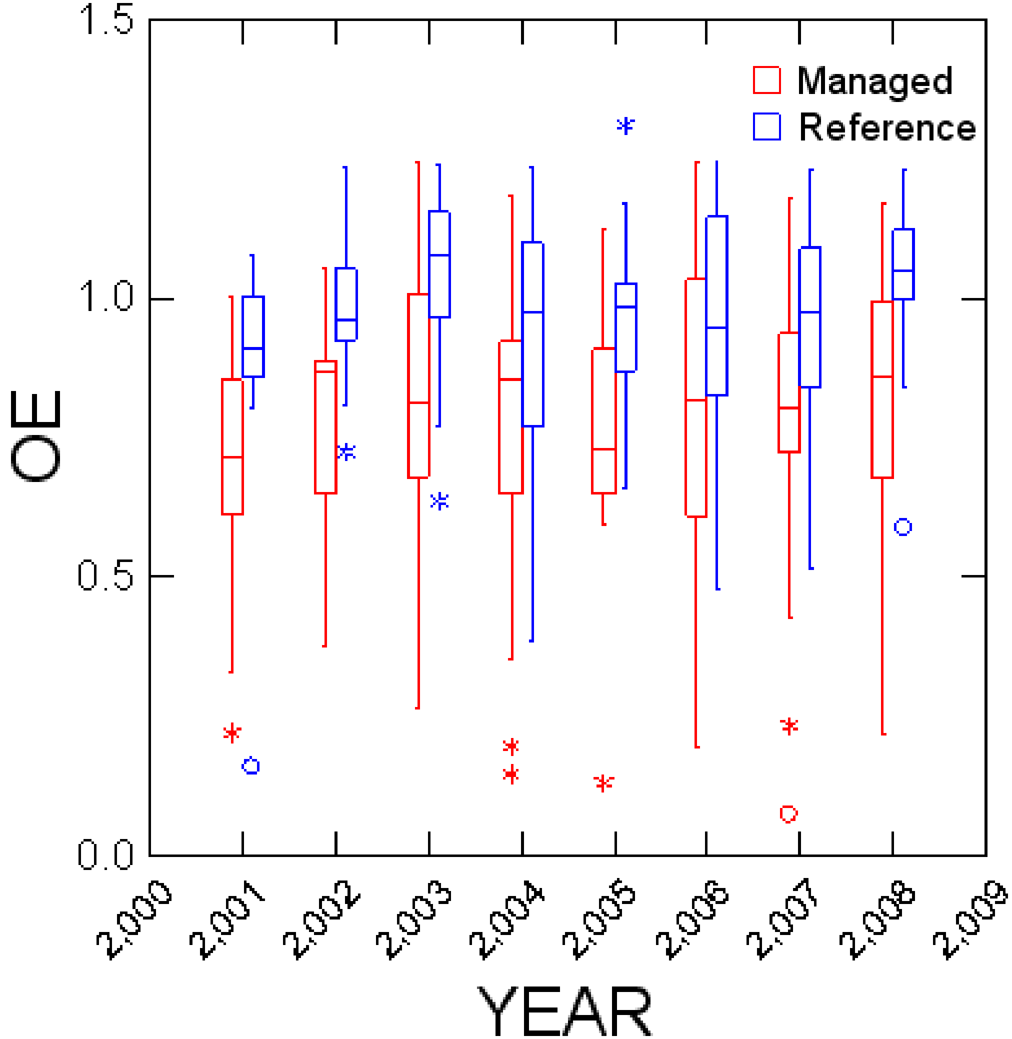



25% of sites / 14% of obs. changed designation



# Results: Is the year effect ecologically significant?

## Difference between reference and managed sites: no year effect ($F_{7, 234} = 0.77$; $p = 0.617$)



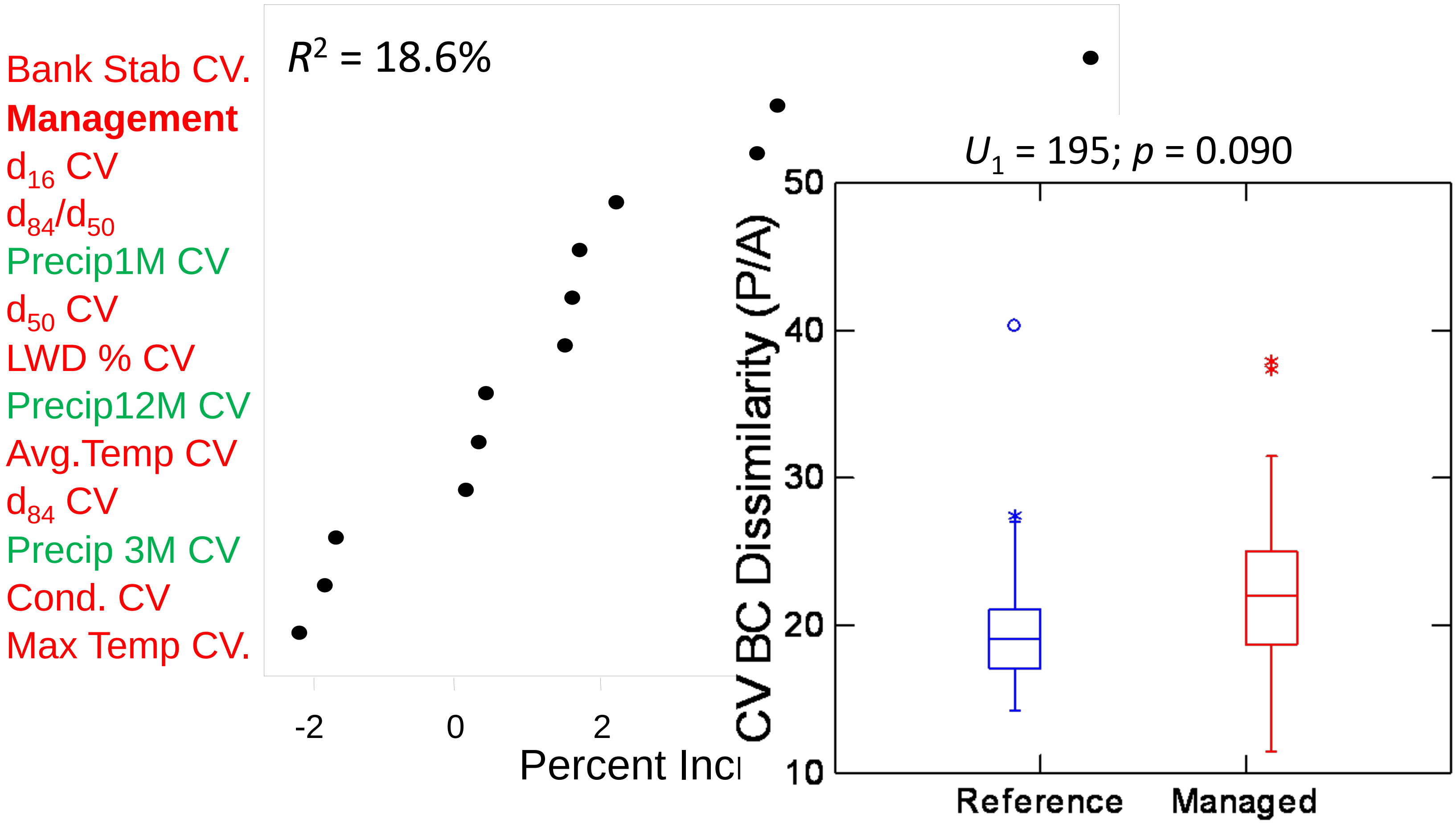
# What components of interannual environmental variability explain macroinvertebrate temporal dynamics?

# Results: Modeling interannual variability

*Modeling approach*: Random forest

*Response*: CV macroinvertebrate persistence

*Explanatory variables*: CV reach and CV climatic variables



# Results: Modeling interannual variability

*Modeling approach*: Random forest

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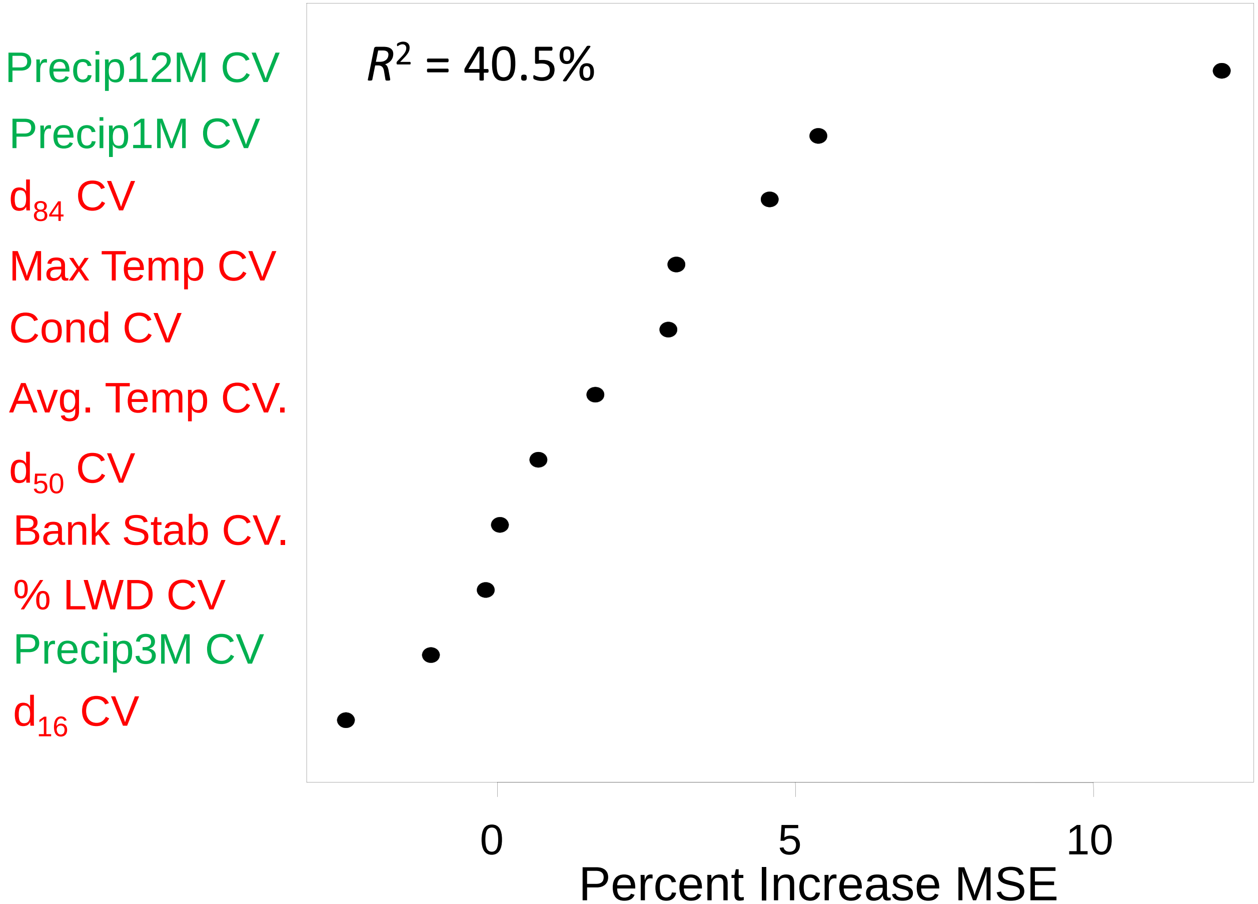
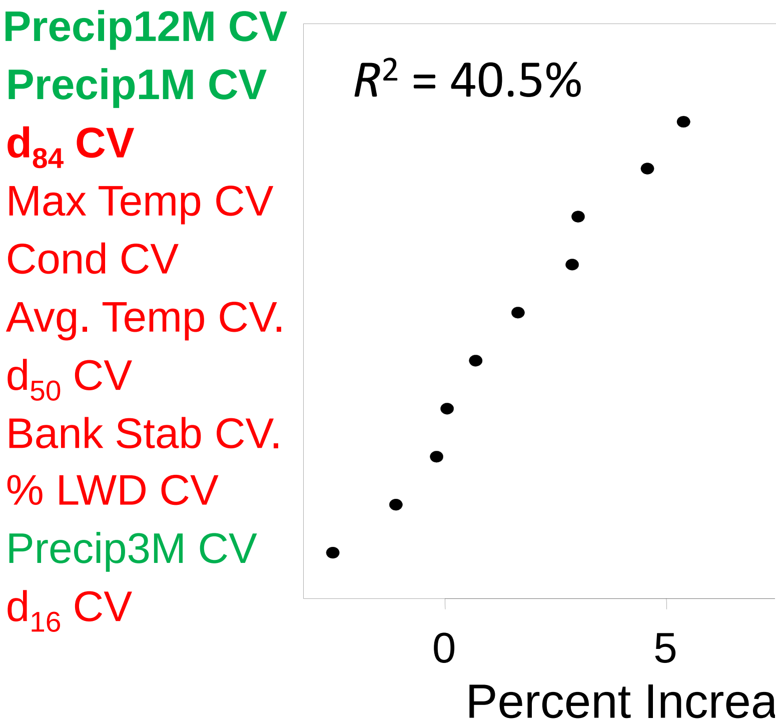
*Explanatory variables*: CV reach and CV climatic variables

Reference: variable importance plot

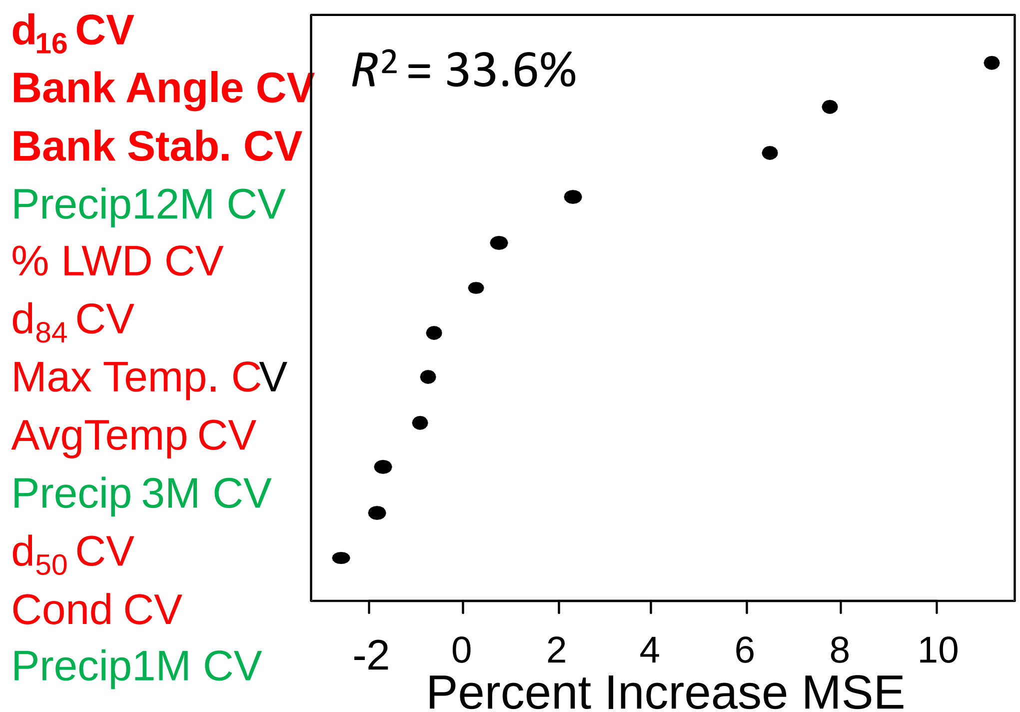


# Results: Modeling interannual variability

Reference: variable importance plot



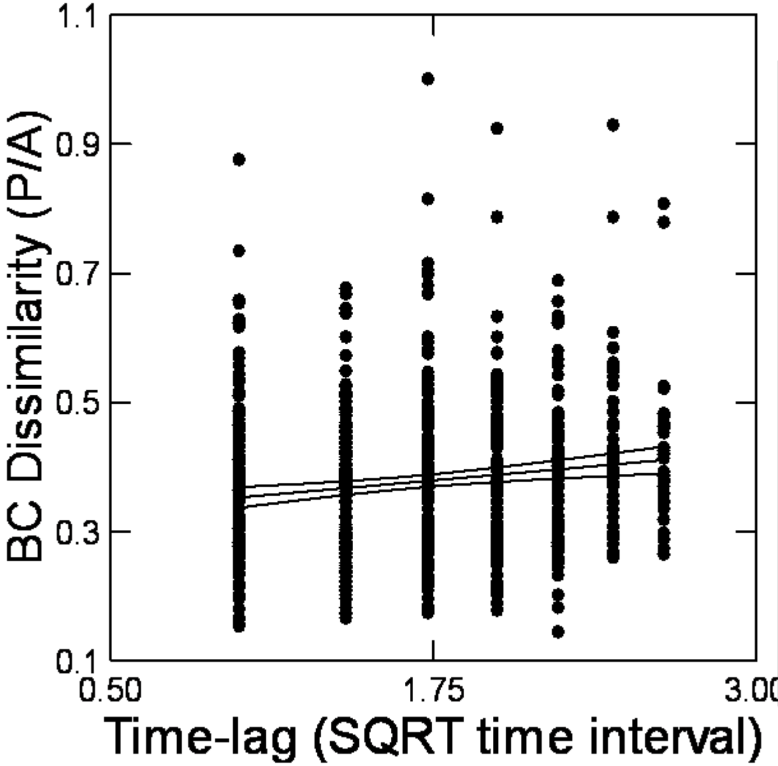

Managed: variable importance plot

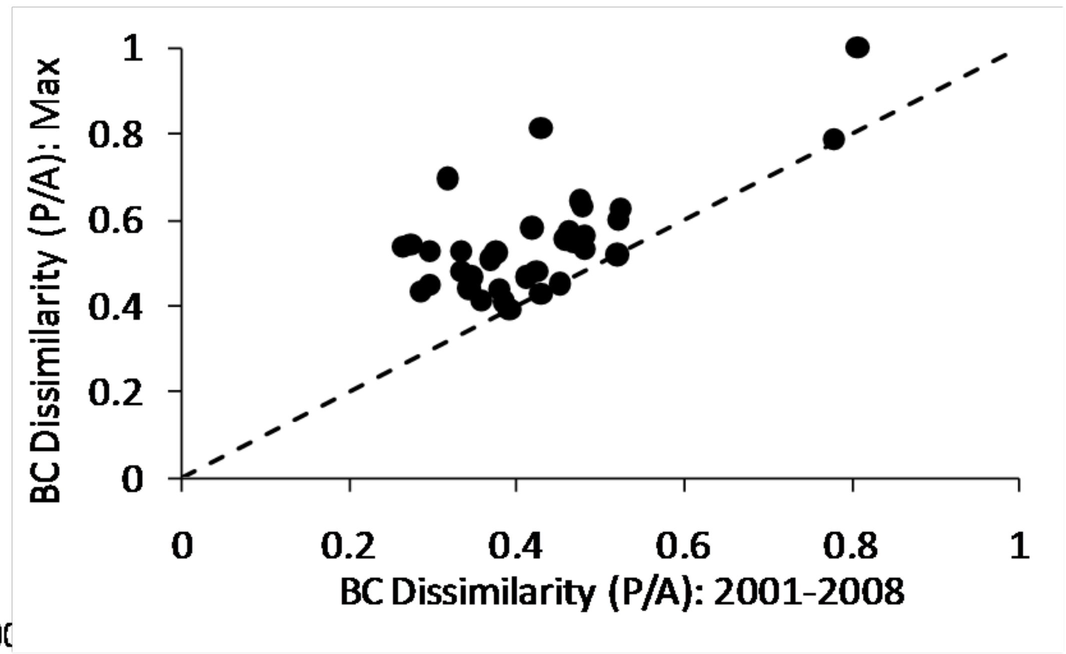


# Results: Characterizing interannual variability

What is the direction or trend of interannual variability?

Time-lag regression
Slope = 0.04; $t$ = 4.5; $p$ < 0.001



# Conclusions

- Average temporal variability among sites:
  - Significant site and year effect
  - Among site variability related to biological condition (degraded > variable than reference), temperature and elevation

- Implications for accurate status and trend assessments:
  - Reference sites: relatively stable, not as confounded by year effect
  - Managed sites: interannual variability > ability to confounded status assessment
  - Reliability of one-time surveys
  - Based on temporally intensive model

# Conclusions

- Env. drivers of interannual variability
  - Differential controls between reference and managed:
    - Natural climatic variability versus reach-scale drivers
    - Climate change implications for reference conditions

- Need for additional analyses attempting to partition variance among multiple sources at large spatial and temporal time frames and/or across stressor gradients